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MATRIX CONTROLLED DISPLAY DEVICE

2nd INTERIM DEVELOPMENT REPORT

PREPARED FOR

NAVY DEPARTMENT
BUREAU OF SHIPS
ELECTRONICS DIVISION

CONTRACT: NObsr 89334

15 SEPTEMBER 1963 TO 15 DECEMBER 1963

GENERAL ELECTRIC
ELECTRONICS LABORATORY
MILITARY COMMUNICATIONS DEPARTMENT
SYRACUSE, N.Y.

2ND INTERIM DEVELOPMENT REPORT

FOR

MATRIX CONTROLLED DISPLAY DEVICE

This report covers the period 15 September 1963 to 15 December 1963

GENERAL ELECTRIC COMPANY
MILITARY COMMUNICATIONS DEPARTMENT
SYRACUSE, NEW YORK

NAVY DEPARTMENT BUREAU OF SHIPS ELECTRONICS DIVISION

CONTRACT NObsr-89334   PROJECT SR-080301; TASK 9475

1 JANUARY 1964

ABSTRACT

This report describes the work accomplished during the second quarter of a contract to develop a feasibility model of a large screen, matrix controlled display device using in-air surface deformation recording and TIRP (Total Internal Reflection Prism) projection techniques.

The TIRP projection system for the optical readout of surface deformations on a thermoplastic or an oil medium has been designed and implemented. Its operation is explained. Optical design considerations are given based on a 64 x 64 element display. The mechanical adjustments required for the alignment of the TIRP optical system and to provide a uniform air gap for in-air recording are discussed.

The implementation of the in-air recording technique using X-Y matrix control has also been completed. Circuitry to drive any desired combination of X-Y matrix electrode intersections at the display medium is described. Also described is the fabrication on a single substrate of matrix electrodes at 5, 10, and 20 line pairs per millimeter with three widths at each spatial frequency. Included is the technique developed to form the electrodes by etching transparent, conductive coatings of indium oxide on a glass substrate. Prior to etching, a pattern of the matrix electrodes is formed by exposing a photosensitive resist through a photographic mask.

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1. PURPOSE

The purpose of the research and development work described in this report is to design, develop, fabricate and furnish a laboratory model of a Matrix Controlled Display Device aimed at satisfying the requirements set forth in Contract NObsr-89334. The program objective is to provide a bright display with ultimate capabilities of 2000 x 2000 elements on a screen 10 feet x 10 feet by using matrix switch control of a surface deformable medium (thermoplastic or oil) to modulate light in the TIRP (Total Internal Reflection Prism) projection system. Achievement of this objective will be demonstrated by a 64 x 64 element feasibility model in which the cells are individually switched. In addition, the matrix drive shall be as compatible as possible with existing ELF system logic, driven by Display Generator Equipment OA-2959 (XN-2)/FYQ-1.

The following are the specific objectives of this program.

(1) The fabrication of glass plates with matrix electrodes at different spacings and widths.

(2) A TIRP projection system for optical read-out.

(3) An infrared heat source for thermoplastic development.

(4) Circuitry to control the heat source and to drive the matrix electrodes.

(5) Assembly of the above components.

(6) Tests to determine cell dimensions, switching speed and switching voltage for an optimum display with respect to contrast ratio, brightness and storage time.

(7) Tests to determine lifetime characteristics of both deformable media.

(8) Delivery of the model consisting of the experimental equipment developed in the course of this contract.

2. GENERAL FACTUAL DATA

2.1 IDENTIFICATION OF TECHNICAL PERSONNEL

The following table is a list of technical personnel contributing to the project together with the approximate man-hours work performed by each during the period covered by this report. In addition, approximately 183 man-hours of model shop and drafting time were expended.

Engineering Personnel	Man-Hours
C. E. Cady	77
C. H. Killam	15
A. P. Orimenko	495

Technical Assistants	Man-Hours
A. H. Hare	63
H. J. Kozlowski	111
M. P. Locaputo	8
R. R. Shoemaker	56

3. DETAIL FACTUAL DATA

3.1 TIRP OPTICAL SYSTEM

The TIRP optical system for the read-out of data recorded as surface deformations on thermoplastic or oil has been designed and assembled. Figure 1 is a schematic of the optical system which has been implemented. For discussion purposes, the system can be divided into two parts, namely, light source and collimation optics and projection optics. The former consists of the light source, iris diaphragm, collimating lens, and mirror A. Its purpose is to provide a collimated light beam whose angle of incidence with respect to the Y matrix substrate is constant. The projection optics consist of the projection lens, mirrors B and C, and the display screen. Its purpose is to form a magnified image on the display screen of the individual display elements on the deformable medium. Common to both parts is the TIRP prism, Y matrix substrate, and deformable medium. Their purpose is the modulation of the light beam in the optical system by surface deformations.

Tests will be performed to determine the optimum display for three matrix cell spacings. Matrix electrodes at the optimum spacing will then be used in the final model of the display device. Consequently, the optical system was designed to accommodate the largest matrix possible of 0.5 inches square at the deformable medium. This size is determined by a 64 x 64 element matrix with cell spacings of 8 mils. This cell spacing is obtained for a matrix with electrodes at a frequency of 5 line pairs/mm.

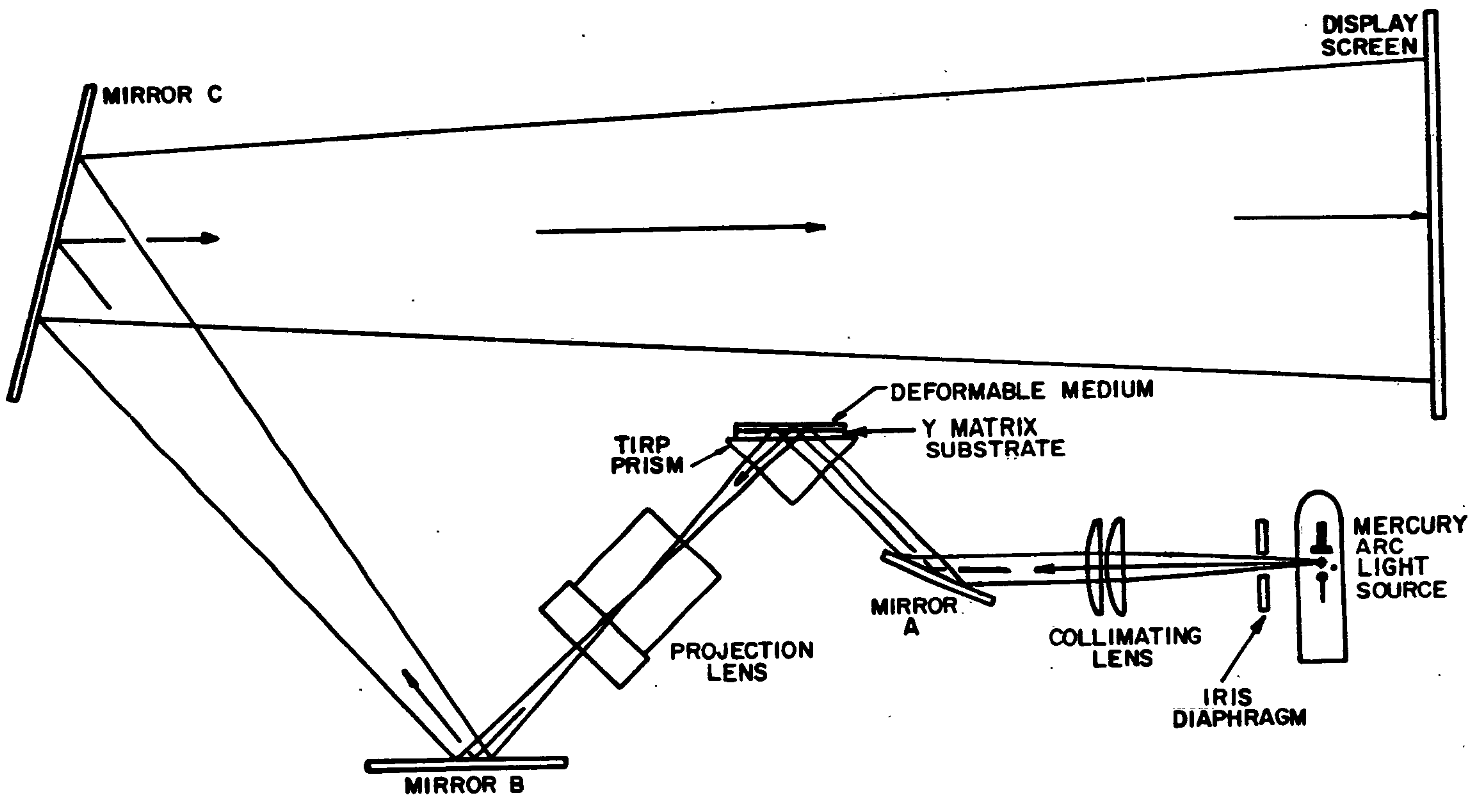

Figure 1. TIRP Optics for Display Device

3.1.1 Light Source and Collimation Optics

An Osram HBO 74 lamp was selected for the light source since it combines high luminous efficiency with intense brightness and concentration of power in a minimum of space. The lamp is a high pressure mercury arc designed for projection purposes and emits about 1800 lumens of light flux. The light source is located at the focal point of the collimating lens. This lens consists of two coated achromatic objectives. Each lens is 54 mm in diameter and has a focal length of 254 mm. The focal length of the combination is approximately half that of a single lens or 127 mm. Light rays emerge from the collimating lens parallel to its optic axis only if a point source is located at the focal point. For a finite source, the light rays emerge at various angles with respect to the optic axis (angle of collimation). To reduce the angle of collimation, an iris diaphragm is used to limit the size of the light source. The iris diaphragm is located 1 3/8 inches from the lamp center. Its circular aperture can be adjusted from 1/8 to 1 5/8 inches in diameter.

Mirror A is 2 x 3 inches and is mounted at a nominal 22 1/2 degrees with respect to the optic axis of the collimating lens. It is a front surface mirror which reflects the incident collimated light so that it enters the TIRP prism normal to the first surface. The light continues through the prism, the Y matrix substrate, and the deformable medium at a nominal angle of 45 degrees with respect to the normal to these media. The critical angle, determined by Snell's Law for light beam behavior at the boundary between two different media, is about 42 degrees. With the deformable medium in its undeformed state, total internal reflection occurs at the

deformable medium and air boundary since the incident light exceeds the critical angle. In its deformed state, the surface of the deformable medium is inclined with respect to the constant incident light beam at an angle which is less than the critical angle. Consequently, total internal reflection cannot occur and a surface deformation results in the removal of light from the reflected beam.

Since there is an air space between the prism surface and the Y matrix substrate, internal reflection would normally occur at this interface. To prevent this, a thin oil layer is used at the interface. Since the index of refraction of the oil is similar to that of the glass prism, the glass substrate, and the deformable medium, the internal reflection surface is effectively translated to the surface of the deformable medium. For clarity, the thin oil layer is not shown in Figure 1.

3.1.2 Projection Optics

The projection lens is a Hektor f/2.5 of 150 mm focal length. It is a standard projection lens commercially available from E. Leitz, Inc. Previously, it was reported that a 100 mm focal length lens would be used. However, the design has been changed to use the present lens in order to obtain a better depth of focus. The projection lens is nominally mounted so that its optic axis is normal to the near surface of the TIRP prism. The light reflected at the surface of the deformable medium is collected by the projection lens. This light from the lens is then reflected by mirrors B and C and finally imaged on the display screen.

The object and image distances with respect to the projection lens are about 6 inches and 10 feet, respectively. These distances result in a magnification of 20 times. With this magnification, the smallest cell spacing of 2 mils at the deformable medium will be 40 mils at the display screen. Since the display screen is located near the test stand, the display elements will be easily resolved.

Mirrors B and C are both front surface mirrors. They are 4 x 5 inches and 8 x 10 inches, respectively. Their positions will be adjusted for convenience in testing the display device. This is also the criteria for locating the display screen near the test stand.

3.2 MATRIX CONTROLLED DISPLAY DEVICE

The mechanical design and construction of the test stand for mounting the various components of the display device has been completed. Figure 2 shows the matrix controlled display device completely assembled. The front panel is the matrix electrode selector consisting of switches to direct the X and Y matrix drive voltages to any desired cell combination. Sixty-four switches in both the X and Y banks have been wired to the matrix electrodes on the X and Y matrix substrates, respectively. Connection to the individual electrodes are made by fingers resting on the beveled edges of the substrates. Thirty-two of the fingers associated with the Y matrix substrate are just visible in Figure 2.

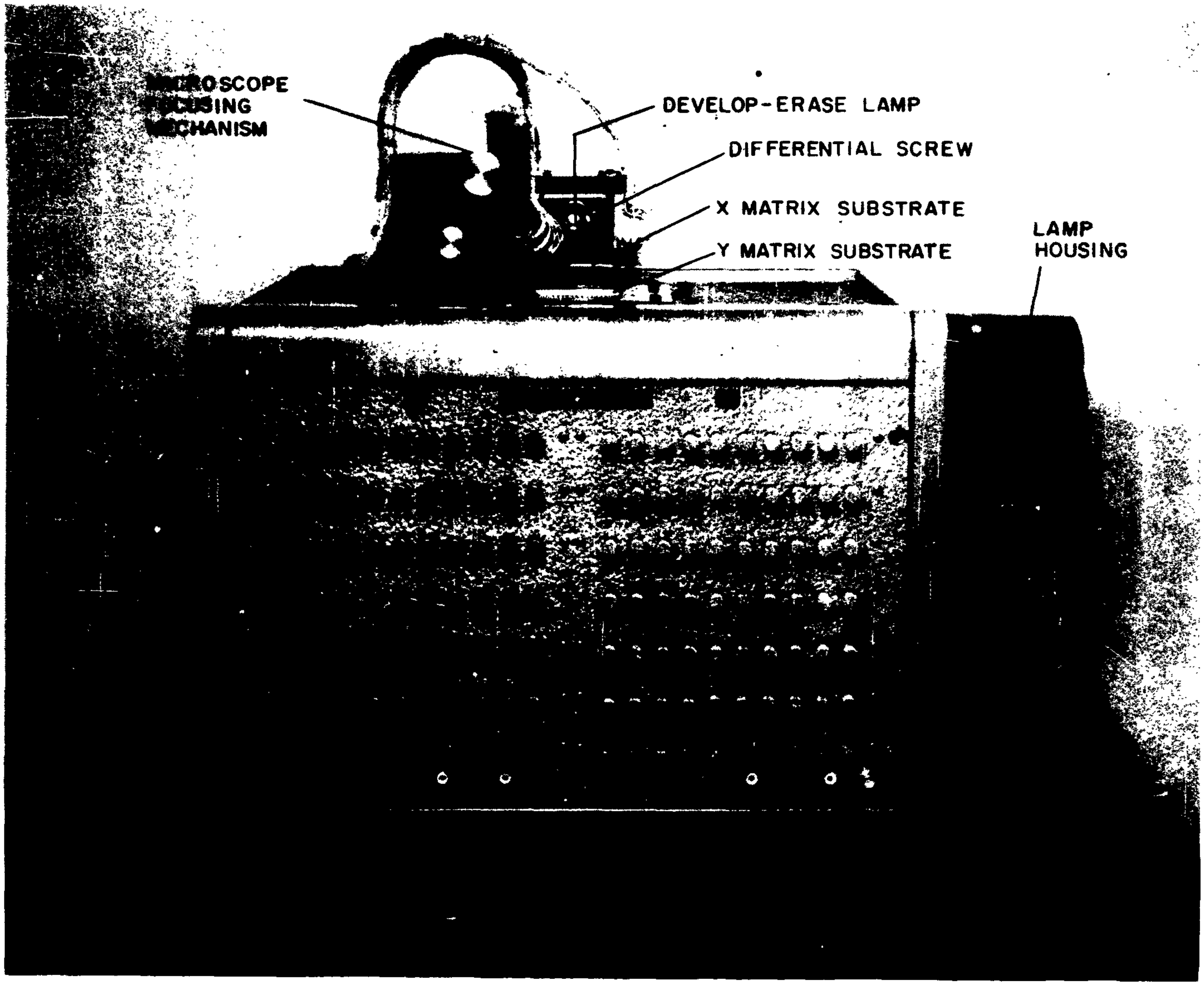

Figure 2. Matrix Controlled Display Device

Figure 3 is a close-up of the X and Y matrix substrates and their finger connectors. In this figure, the assembly driven by the microscope focusing mechanism has been detached and mounted at a right angle to show the X matrix substrate. The reflector in the develop-erase lamp can be seen behind the X matrix electrodes. In the foreground is the Y matrix substrate. The bright lines, which seem to be on this substrate, are actually the edges of the TIRP prism under it. Both the X and Y substrates are rigidly held by the finger connectors.

Referring to Figure 2, the lamp housing is mounted to a side panel of the test stand. The air gap between the X matrix substrate and the deformable medium on the Y matrix substrate is controlled by the microscope focusing mechanism. This mechanism moves the X matrix substrate vertically to provide a variable air gap. A travel of 2.5 inches and 0.100 inches is obtained by adjusting the focusing mechanism coarse and fine controls, respectively. The fine control has a one micron per division scale which will allow accurate control of the air gap.

Four differential screws, one of which is clearly shown in Figure 2, will be used to adjust for parallelism between the optically flat substrates. This adjustment is necessary in order to obtain a uniform air gap for in-air recording. The differential screws are threaded for 1/4-20 at the top and 10-24 at the bottom. One turn of the screw results in the bracket, holding the X matrix substrate, moving about 8 mils. This is the difference between the two thread pitches. A differential screw is located at each corner of the substrate mounting bracket.

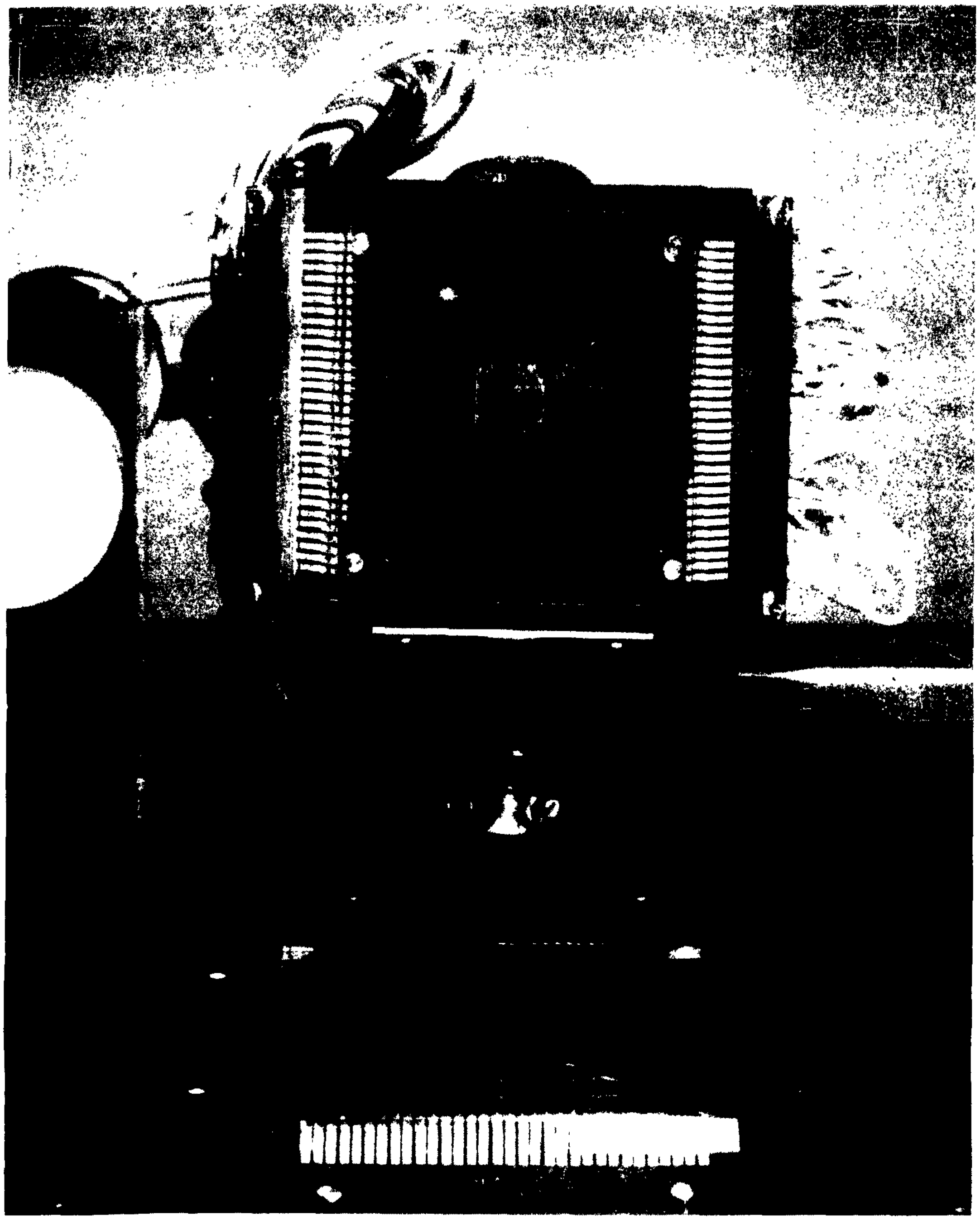

Figure 3. X and Y Matrix Substrates

The develop-erase lamp shown in Figure 2 is a 500 watt CZA projection lamp. Radiant heat from this lamp is required for the development and erasure of thermoplastic deformations. A hole, seen in Figure 3, has been cut out of the X matrix substrate mounting bracket to permit passage of radiant heat to the thermoplastic medium. When the deformable medium is oil, the develop-erase lamp is not utilized.

Figure 4 shows the display device with the matrix electrode selector panel swung downward. All the components of the TIRP optical system mounted on the test stand are visible except for the prism. The prism is below the Y matrix substrate and is rigidly clamped to a plate attached to the top plate of the test stand. The power supply for the HBO 74 lamp is mounted to the rear frame of the test stand.

To center the HBO 74 light source on the optic axis of the collimating lens, three thumb screws provide vertical and horizontal movement of the lamp in a plane perpendicular to that axis. The collimating lens is located at a nominal distance of 4 13/16 inches from the lamp center. This is the approximate focal length of the lens optically measured to the surface nearest the lamp. The lens mount can be moved along horizontal slots to permit adjustment of the lamp to lens distance about the nominal focal length. These slots are in the brackets to which the lens mount is attached. One of the brackets was removed to expose the lens mount and mirror A. It can be seen on the bottom panel of the test stand.

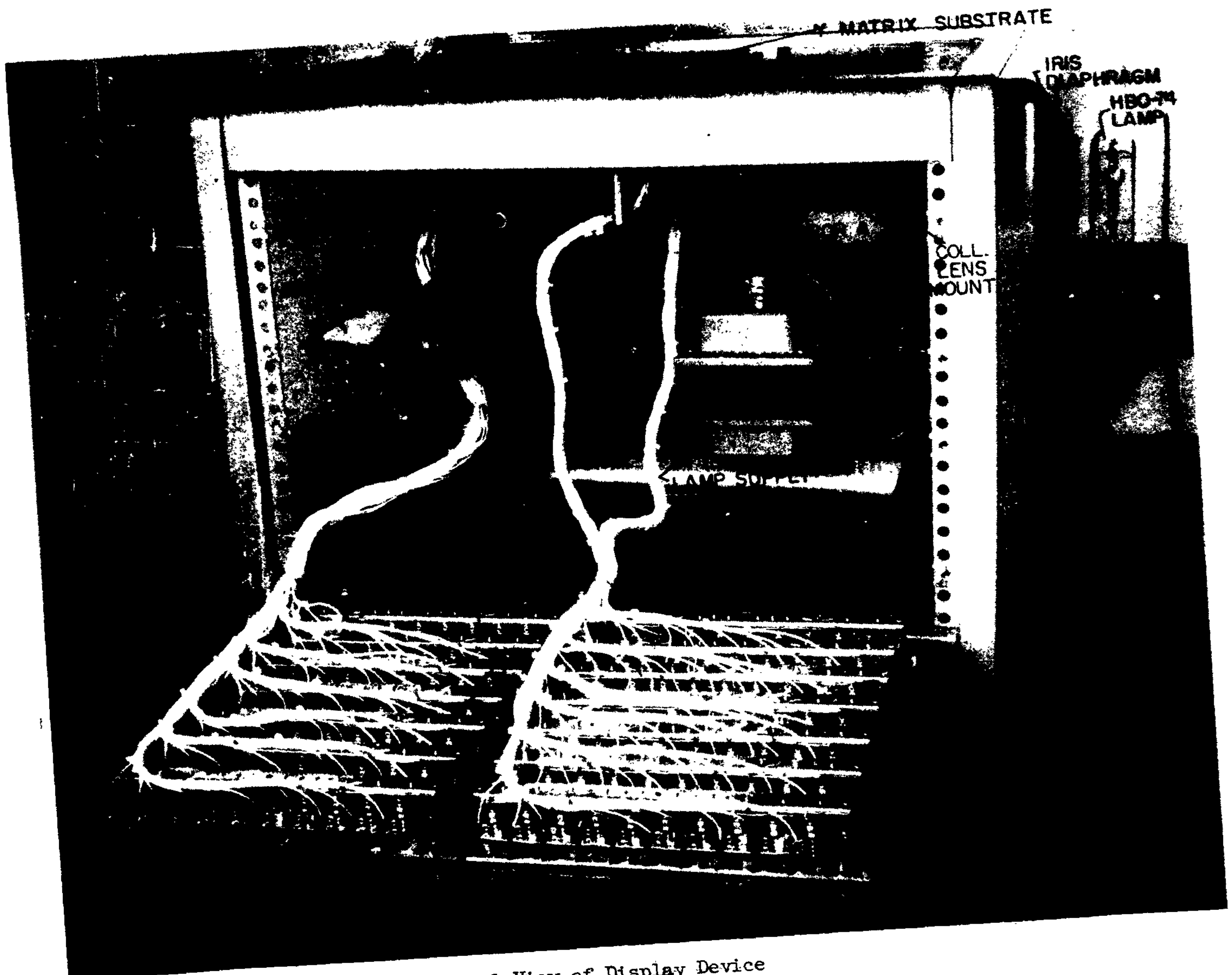

Figure 4. Internal View of Display Device

Mirror A was located to keep the distance from the collimating lens to the prism at a minimum consistent with ease of mechanical adjustment and assembly. A minimum distance is desirable in order to reduce the spread of the collimated light beam. Minimum spread results in maximum light incident on the deformable medium. Spread occurs because the light beam has some finite angle of collimation.

The intensity of the light beam reflected at the deformable medium is affected by the deviation from the critical angle of the incident angle. Although the nominal angle of incidence is 45 degrees, it may be desirable to have an incident angle closer to the critical angle of 42 degrees. Therefore, rotational movement of mirror A, in order to vary the incident angle of the collimated light beam, is provided. This movement is obtained simply by rotating the mirror mount. Rotating the mirror also changes the point of incidence of the light beam center. To keep the point of incidence fixed at the center of the deformable medium on the Y matrix substrate, mirror A mount can be moved along horizontal slots. Thus, the point of incidence as well as the angle of incidence of the collimated light beam is adjustable.

A change in the angle of incidence results in a similar change in the angle of reflection of the light beam since the two are equal. Referring to Figure 1, it can be seen that the center ray of the reflected beam moves in a circular arc about a fixed point at the deformable medium as the incident angle at this point varies. This results in the reflected beam being off center with respect to the

optic axis of the projection lens. To keep the reflected beam center and the projection lens optic axis collinear, the projection lens can also be moved in a circular arc about a fixed point at the deformable medium. This is accomplished simply by moving the projection lens mount along circular slots. One such slot is visible in Figure 4. The design permits an angular movement of ± 7.5 degrees about a nominal 45 degrees with respect to the horizontal. To insure the ability to focus, the projection lens was mounted so that its minimum object distance to the center of the deformable medium is less than its focal length of 150mm.

Mirror B moves in common with the projection lens when the lens is moved along the circular slots. This insures that the beam emerging from the projection lens is always centered on mirror B. However, this also changes the image position on the display screen. Therefore, mirror B can be rotated independently of the projection lens. As previously discussed in section 3.1.2, mirror B will be adjusted in conjunction with mirror C to position the image on the display screen located near the test stand.

The adjustment of the air gap and the alignment of the TIRP optical system will be completed early in the next interim period. In-air matrix controlled recording on the deformable medium will then commence. It is expected that most of the next interim period will be devoted to testing of the display device.

3.3 MATRIX ELECTRODE FABRICATION

The fabrication of the matrix electrodes involves several processing steps given in the following list.

(1) Prepare artwork of matrix electrodes magnified 64 times.

(2) Make photographic mask of electrodes by reduction of the original artwork.

(3) Coat glass substrates with transparent conductive layer of indium oxide.

(4) Apply coating of KPR (Kodak Photo Resist) over the indium oxide layer.

(5) Expose KPR through the photographic mask and develop to form the electrode image in the form of hardened KPR.

(6) Etch to remove the indium oxide not protected by KPR.

(7) Remove resist with solvent to leave the matrix electrode pattern.

(8) Evaporate low resistance contacts for fingers connecting the matrix electrodes to the external drive circuitry.

All the preceding steps have been completed. For economy, the initial experiments were performed on microscope slides. When the processing techniques were sufficiently developed to assure success, the matrix electrodes were fabricated on the optical flat substrates to be used in the display device. A completely fabricated 70 mm square substrate with the matrix electrodes, fanned conductors, and low resistance contacts is shown in Figure 5. The initial matrix to be tested contains twenty-one electrodes at each of three frequencies (5, 10, and 20 lines/mm). In addition, each frequency group contains seven electrodes at each of three duty cycles (20, 50, and 80%). Once the cell dimensions for an optimum display have been determined, the matrix electrodes will be fabricated at the optimum spacing and width.

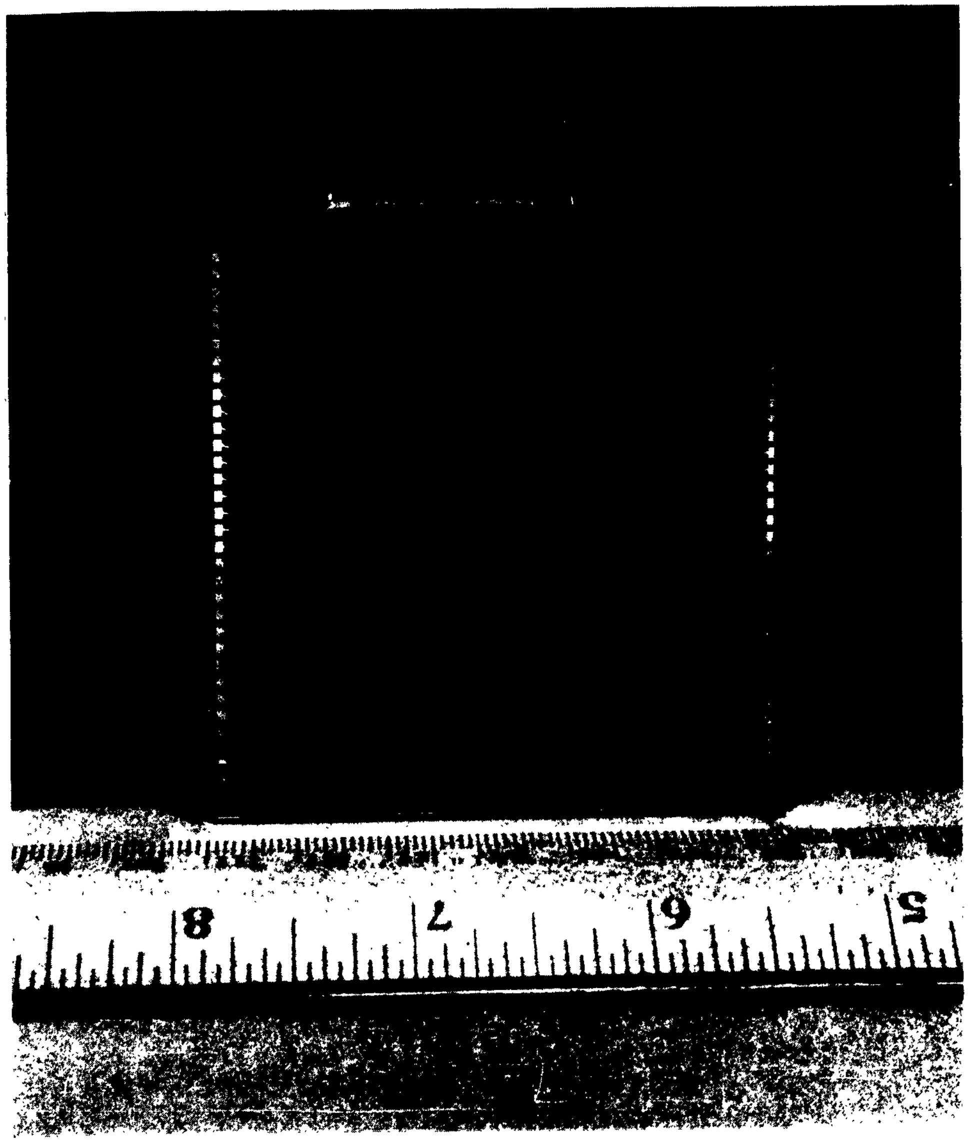

Figure 5. 70 mm Square Substrate with Matrix

3.3.1 Photographic Mask Preparation

The artwork preparation was completed during the first interim period and was discussed in the first interim report. At that time it was reported that difficulties were encountered in making the final reduction step in the multiple step reduction of the artwork to the final photographic mask. To solve the problem, Kodak High Resolution Plates rather than Kodalith Ortho Film, Type 3 were used in the final reduction step. Although the results were much better than with film, the seven electrodes at 20% duty cycle and 20 lines/mm were not sharp and had poor contrast. The mask was used to expose several KPR coated slides at times ranging from 9 to 20 minutes. Since a KPR pattern of the fine lines could not be obtained, a new mask was made.

The fine lines on the new mask were sharper and brighter compared to the first mask. With the new mask, good KPR patterns of the fine lines were obtained. Figure 6 shows the final mask used for exposure of the KPR coating. Exposure of the KPR occurs through the clear lines of the mask. To center the matrix on the substrate in the vertical direction, microscope slides were attached to the mask with masking tape. Next to the slides can be seen four clear areas which were formed by removing the emulsion from the mask with a knife. The inside edges of these areas are used to center the matrix on the substrate in the horizontal direction. Index marks extending from the four outer contacts were originally intended for horizontal alignment. However, these were not properly located necessitating the method described. The boundary,

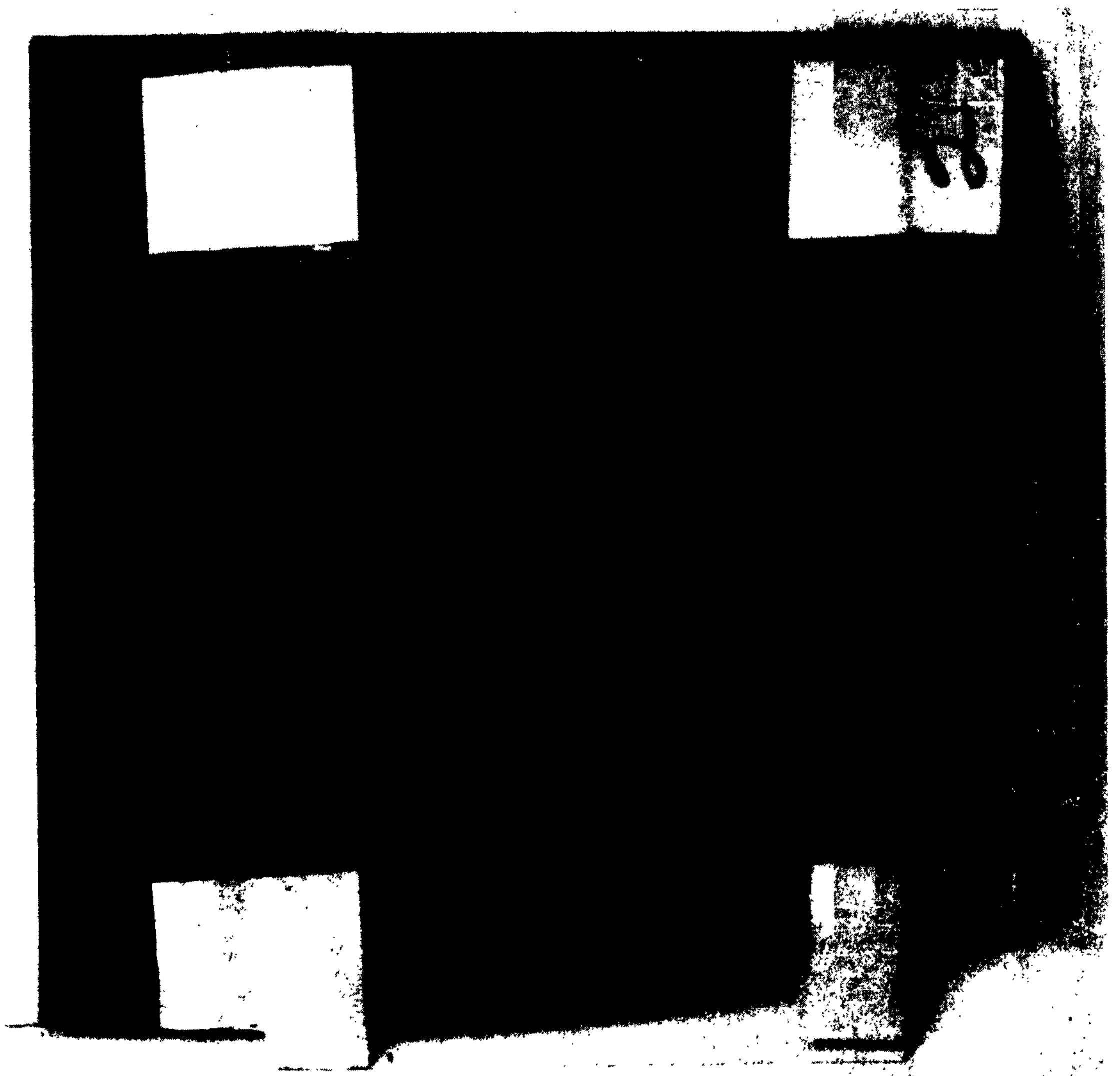

Figure 6. Photographic Mask Magnified 1.5 Times

formed by the inside edges of the two microscope slides and the four clear areas, registers with the 70 mm square boundary of the substrate. Microscope measurements along the center of the mask showed that the matrix electrode spacings and widths were within 2% of their design values.

3.3.2 Matrix Fabrication on Microscope Slides

The coating of microscope slides and 70 mm square substrates with an evaporated indium oxide layer was performed by the General Electric Cathode Ray Tube Operation in Syracuse. Prior to receipt of these glass plates, some of the initial experiments were made using slides with indium oxide coatings applied by spraying in an electric oven at 500°C.

Seven slides with sprayed indium oxide coatings were coated with KPR. Times ranging from 9 to 20 minutes were then used to expose the KPR through the first photo mask. The best KPR pattern was obtained at 11 and 12 minutes. As previously explained, the fine lines of the matrix were not obtained and a second mask was then ordered. In the meantime, a few of these slides were etched with the powdered zinc and hydrochloric acid solution used in previous experiments. This solution resulted in the removal of the KPR and the oxide film. When concentrated hydrochloric acid was used, the KPR was removed and the oxide film did not etch.

By using a heated, dilute solution of HCl, good etching results were obtained. The KPR softened but was not removed. Also, the indium oxide etched but not completely. Since the spraying technique at 500°C results in the oxide film fusing with the glass, it is very difficult to etch the indium oxide completely. However, the glass plates coated by evaporation are processed at about 275°C. At this temperature, good adhesion between the oxide and glass is obtained without fusing. Since evaporated slides were now available, it was decided to halt any further development work with sprayed slides.

Three slides with evaporated indium oxide coatings were then coated with KPR. They were exposed at the optimum exposure time (11 and 12 minutes) determined with the sprayed slides. The KPR pattern, with the exception of the fine lines, was good on all the slides. Since the new photo mask was still being made at this time, the fine lines were not expected to be obtained. Etching these slides with the heated, dilute HCl solution gave encouraging results. Although the KPR softened, the indium oxide was completely etched off. The KPR softening problem was overcome by etching for one minute, rinsing in water, and then heating for one minute under an infrared lamp to harden the KPR again. Repeating this process four times gave excellent results.

When the second photographic mask was delivered, it was necessary to determine the optimum KPR exposure time again. The best KPR pattern of the matrix electrodes was obtained at an exposure time of 14 minutes.

At this exposure, all the electrodes including the fine lines (narrow conductors at 20 lines/mm) were obtained. During these experiments, it was learned that baking of the slide after coating with KPR was necessary in order to obtain the fine lines. These slides were then etched. However, the total time required for a complete etch varied from 4 to 9 minutes. Upon removal of the KPR with acetone solvent after etching, the indium oxide was also removed from some of the slides.

The etching time variation and the loss of the indium oxide on some slides could not be correlated with differences in the KPR processing or etching techhniques. However, it was learned that the indium oxide coatings are evaporated on six slides at one time. Apparently the outer slides receive a thinner and less uniform coating compared to the center slides. It was concluded that these differences accounted for the variation in the results. Since it was not known which were the outer slides, this conclusion could not be verified. Nonetheless, it was decided to proceed with the fabrication of the matrix electrodes on the 70 mm square substrates. Since each substrate occupies about half the area of six microscope slides (1 x 3 inches/slide) and a single substrate is coated at one time, a uniform indium oxide layer could be expected.

3.3.3 Matrix Fabrication on 70 mm Square Substrates

All the 70 mm square substrates with an evaporated indium oxide layer ordered have been received from the Cathode Ray Tube Operation. Of the fifteen substrates delivered, seven were measured on a Jarrell-Ash

Microphotometer to determine their transmissions. All seven had a transmission within ±1% of 80%. Since an uncoated substrate had a transmission of 90.5%, the indium oxide transmission is 88.4%.

Using the techniques developed with the microscope slides, matrix electrodes were fabricated on five of the 70 mm square substrates. Prior to etching, the KPR pattern of the electrodes was examined with a microscope. The substrates were then etched. Etching times of 7, 9, and 14 minutes were required. Removal of the indium oxide, experienced with the microscope slides, did not occur when the KPR was removed from these substrates. Apparently, the conclusion that the loss of the oxide on some slides is an evaporation problem was correct. However, this same conclusion does not explain the etching time variation. The reason for this variation is not known.

After the KPR removal, the electrode pattern was examined with a microscope. Most of the matrix electrodes were obtained on the substrate. The seven electrodes in the 20 lines/mm group at 80% duty cycle were shorted to each other. In this same group, the electrodes at 20% duty cycle were very thin and some had opens. Both problems were traced to the photographic mask. The electrodes on the mask were too wide in the former case and were too low in contrast in the latter case. Since the mask used was the best that could be made from the original artwork, these problems could only be corrected by making new artwork.

The time required to make new artwork and a new mask was not warranted because the present matrix configuration is not final. It is being used to determine optimum cell dimensions prior to fabrication of the electrodes at the optimum electrode spacing and width. Since enough of the electrodes in the 20 lines/mm group at 20% duty cycle were obtained to allow their evaluation, only one cell dimension (that formed by the 20 lines/mm electrodes at 80% duty cycle) out of the nine to be evaluated was not obtained. Therefore, it was decided to proceed with the program using the five substrates presently completed.

The five completed substrates were checked for matrix centering by measuring the distance from the matrix boundary to the nearest substrate edge. These measurements indicated that the matrix was centered within 10 mils in both directions for four of the substrates. One substrate was centered within 40 mils. Since the electrodes were made 46 mils longer than would be required for a perfectly square matrix, these deviations in matrix centering will not result in the loss of any matrix intersections.

To provide low resistance contacts along the beveled edges of the substrate, a nichrome and then an aluminium layer were evaporated over the induim oxide contacts. An evaporation mask to accomplish this is shown in Figure 7. It was made by forming the reverse KPR pattern of the contacts on 5 mil phosphor bronze material. The material was then etched completely through. Next, a 45° bend was made in order

Figure 7. Evaporation Mask

to make the contacts of the evaporation mask fit flat against the substrate beveled edges. A hole was punched out to prevent damage to the matrix since the mask and substrate are in contact. When the mask was fitted to the substrate, it could be made to lay flat on only one beveled edge at a time. To insure a flat fit on each beveled edge, the evaporation mask was cut in half as shown in Figure 7.

Two aluminium plates were made to hold the evaporation mask against the substrate. The mask and the substrate are sandwiched between the two plates. In the foreground of Figure 8, the complete assembly is shown ready for evaporation. The back of the unit is shown as a reflection in a mirror. A hole was punched in the back plate to prevent scratching of the substrate in the area below the matrix. This area is in the light path of the TIRP optical system. After evaporation, adjacent contacts on the substrate were checked for shorts with an ohmmeter. None of the contacts were shorted except for those associated with the shorted matrix electrodes at 20 lines/mm and 80% duty cycle. The evaporated contacts were slightly wider than the mask. In the final model, this will be overcome by making the contacts narrower to allow for fill-in during evaporation of the low resistance material. The evaporated contacts can be seen in Figure 5.

Figure 8. Assembly for Evaporation of Low Resistance Contacts

A few of the fanned conductors, connecting the matrix electrodes to the beveled edge contacts, had opens. Those nearest the beveled edge were closed by applying silver paint with a fine brush. In retrospect, the fanned conductors should have been made wider than 6 mils to minimize opens. This will be done in the fabrication of the final matrix. Of the five substrates completed, one will be used for the X matrix. Another will be used for the Y matrix with a deformable medium of oil. The remaining three, also for the Y matrix, are presently being coated with thermoplastic.

3.4 DISPLAY DEVICE CIRCUITRY

3.4.1 HBO 74 Power Supply

The power supply required to start the arc and limit the current of the HBO 74 lamp is shown schematically in Figure 9. Transformer T1 merely steps up the line voltage by 2 to 1 to provide 220 VAC at the input to the choke for the lamp supply. Ordinarily, the lamp is ignited automatically by starter ST 192. When the DPST switch is closed, voltage across the starter produces a glow discharge between the U-shaped bimettalic strip and the fixed contact. The heat generated actuates the bimettalic strip closing the contacts. This shorts out the glow discharge, so the bimetal cools and in a short time the contacts open. The resulting inductive voltage kick from choke L1 is then sufficient to start the lamp.

Once the arc is ignited, a low resistance path is formed through the lamp. Since the ignition circuit resistance is then much higher than the lamp resistance, the starter is effectively out of the circuit. If the lamp fails to start for some reason, the starter will switch off automatically. To get the starter ready for operation again, it is reset by pressing its push button after a cooling time of a minute or two. The choke, in addition to its starting function, is a ballast to insure proper lamp operating characteristics. The lamp is rated for 75 watts at an operating current of 1.6 to 1.85 amps. In Figure 4, the rear view of the HBO 74 power supply chassis can be seen.

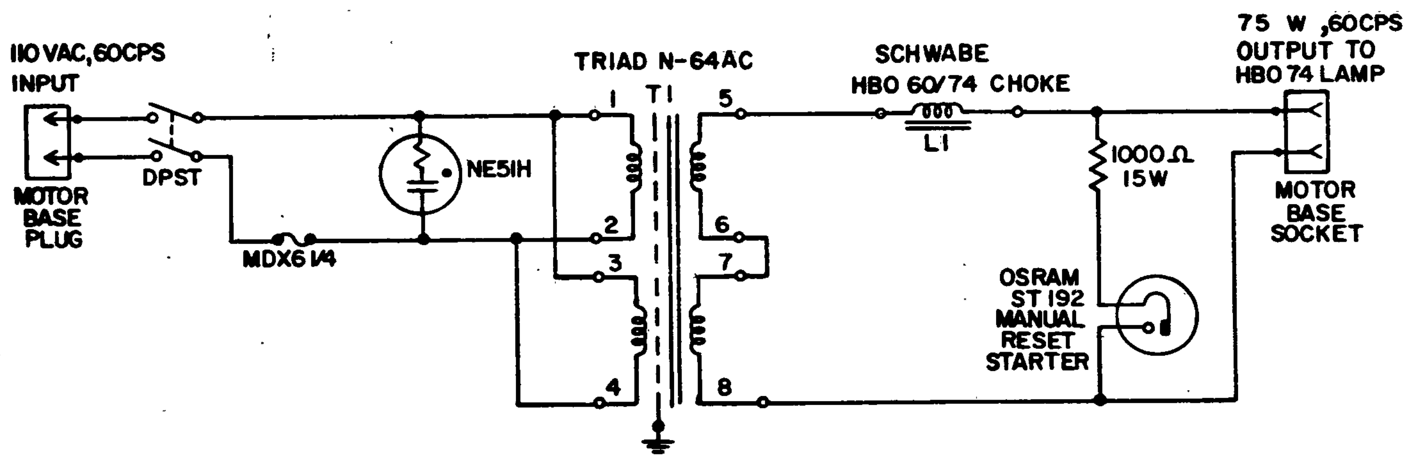

Figure 9. HBO 74 Power Supply Schematic

3.4.2 Matrix Electrode Selector

Drive voltages are directed to any desired combination of X-Y matrix intersections by the matrix electrode selector (Figure 2). Switches in both the X and Y banks have been numbered from 1 to 64 for the 128 electrodes required in a 64 x 64 element display.

A schematic diagram of the matrix electrode selector is shown in Figure 10. The drive voltages are applied to the normally open contacts on the push button switches via one megohm resistors. These resistors limit the current to protect the matrix electrodes in the event of shorts between electrodes on the same substrate or between electrodes on the X and Y substrates.

When an X switch is depressed, the associated electrode is connected to a positive DC potential from the external DC supply. Depressing a Y switch connects its associated electrode to the external pulser. Initiating a microswitch on the pulser then applies a negative pulse to that electrode. The two voltages across the matrix intersections, selected by the X and Y push buttons depressed, sum to produce surface deformations on the deformable medium. If the switch associated with an X matrix electrode is not depressed, the electrode is at ground potential. In this case, the pulser voltage is below the threshold level required for a surface deformation to occur.

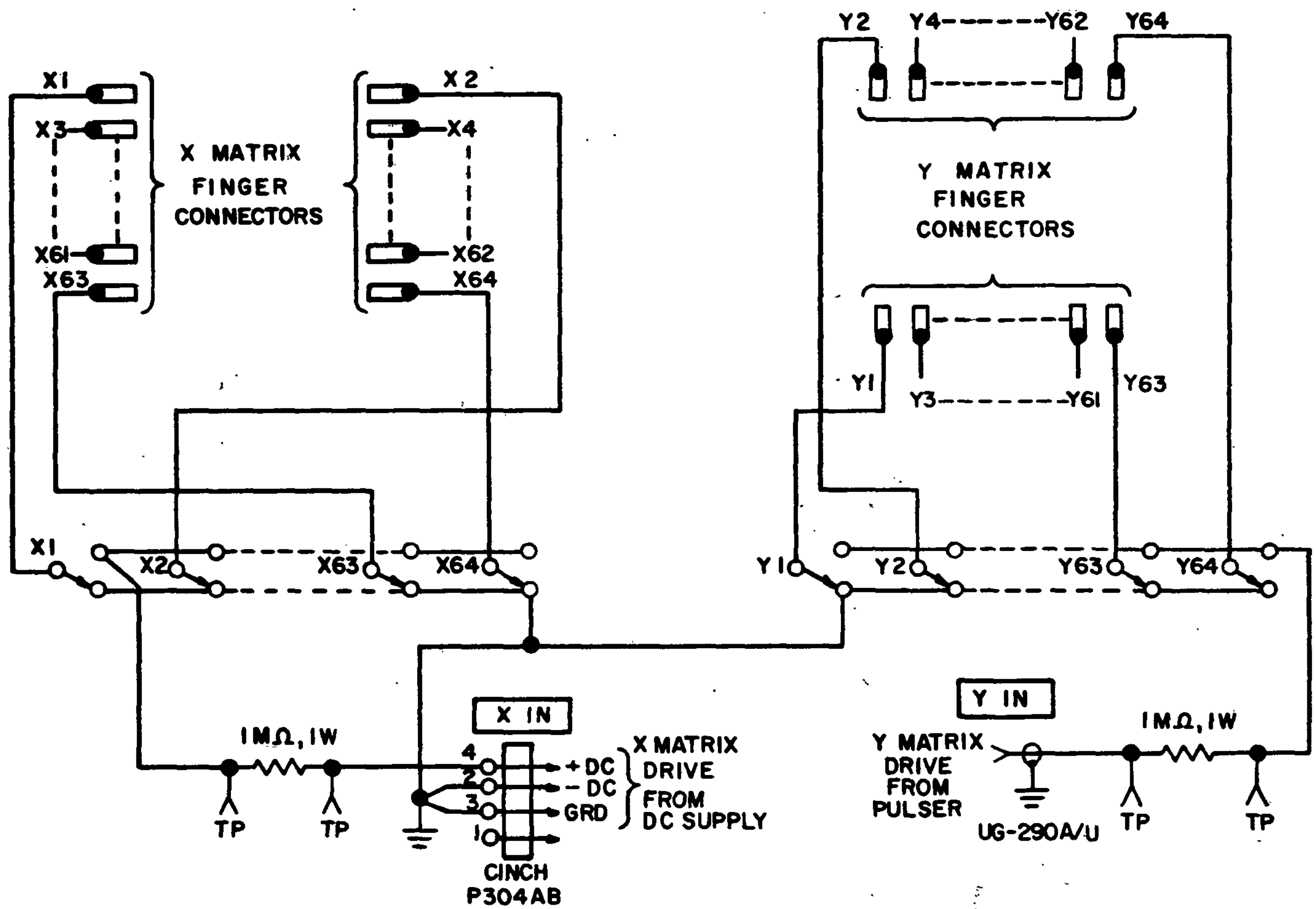

Figure 10. Matrix Electrode Selector Schematic

When the matrix electrodes were fabricated, alternate electrodes were fanned out to alternate beveled edges on the substrate. If one were to number these electrodes consecutively from 1 to 64, all the odd electrodes would go to one edge and all the even to the other edge. In order to have consecutive switches correspond to consecutive electrodes, all the odd numbered switches were wired to one edge and all the even numbered switches were wired to the other edge. This is shown in Figure 10 where the finger connectors are drawn to correspond to their actual physical location in the test stand (Figure 2) viewed from the top while standing in front.

3.5 PROJECT PERFORMANCE AND SCHEDULE

Figure 11 shows the breakdown of the project into the tasks to be performed during the entire period covered by this contract. In addition, the work performed and an estimated schedule of projected operations, as of the end of the second interim period, are shown. The program is about five weeks behind the schedule projected at the end of the first interim period. This was due to the unavailability of personnel to do the work on a full time basis.

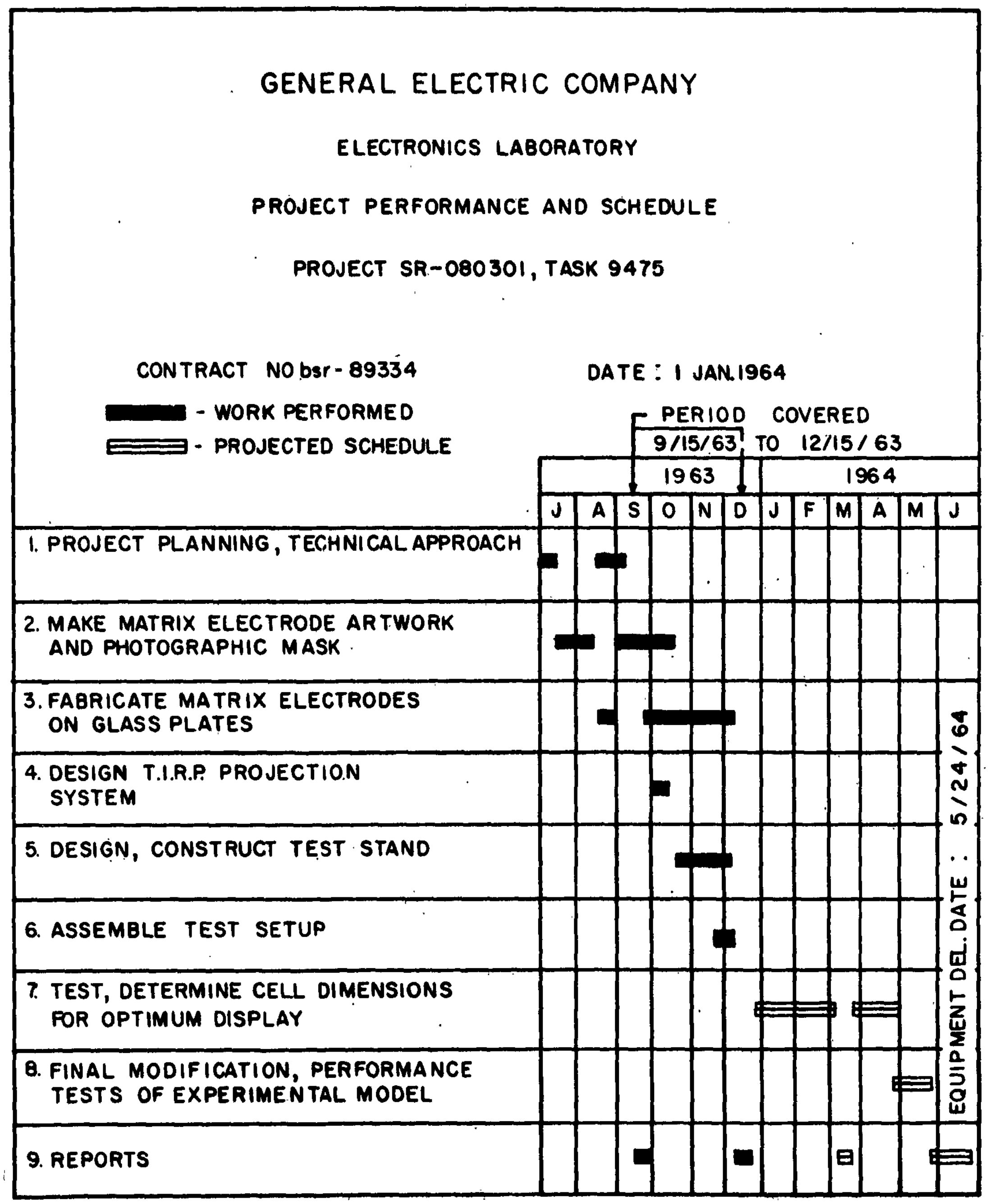

Figure 11. Project Performance and Schedule Chart

4. PROGRAM FOR NEXT INTERVAL

During the third interim period, the majority of time will be devoted to testing the display device. Specific tasks to be carried out are as follows:

(1) Coat three 70 mm square substrates with thermoplastic.

(2) Adjust X matrix substrate for parallelism with respect to Y matrix substrate to provide a uniform air gap for in-air recording.

(3) Align light source, collimation optics, and projection optics of TIRP optical system.

(4) Determine time duration of radiant heat required to develop and erase thermoplastic deformations.

(5) Test to optimize display as a function of matrix drive and cell dimensions with both deformable media (thermoplastic and oil).

(6) On the basis of cell optimization tests, prepare artwork and photographic mask at a single electrode spacing and width.

(7) Initiate matrix fabrication with optimum electrode spacing and width on 70 mm square substrates for final model of display device.